INTERDEPARTMENTAL CORRESPONDENCE

Raytheon

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ORG: 23-CB-11
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REF: Y0012914

SUBJECT: Response to Calibration ATBD Comments

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This memo contains a listing of the three sets of comments received from Frank De Luccia on the VIIRS Calibration ATBD followed by Raytheon responses. These response were primarily put together by Jim Young (as indicated by his preceding initials), or other persons as indicated. Raytheon responses are in blue font.

Raytheon notes that many of the questions or issues raised by Frank are complex. Raytheon is using this memo to provide summary level responses and requests that where more detailed responses are required they be addressed via a telecon and/or meeting.

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Comments on VIIRS Radiometric Calibration ATBD, Version 5, Revision 1, May 2002
F. De Luccia
19 July 02

Part 1: Comments on Emissive Band Calibration (Sec. 3.3.2 Emissive Bands)

(1) Eq (18) is incorrect and incomplete as applied to VIIRS:

(18) $L_{BCS\_PATH} = RVS_{BCS}\, \varepsilon_{BCS}\, L(T_{BCS}) + (1- RVS_{BCS})L(T_{HAM}) + L_{BKG}$

This equation is correct for MODIS, in which the analog of the HAM is the front-end scan mirror and L_{BCS_PATH} is the radiance following reflection from the MODIS scan mirror. However, for VIIRS the RTA is upstream from the HAM and its transmission must be taken into account. Note that since the second term on the RHS is the emission from the HAM, the point of reference for all the radiance terms must be the same and must be the entrance aperture of the aft optics. JBY1: I agree the equation needs to be modified. Thank you for recognizing this error. Several other equations throughout the ATBD covering emissive region will need similar modifications. Eq (18) is incomplete in that it does not include the reflection of the background due to the RTA and other cavity structures from the HAM directly into the aft optics. JBY2: It is true that Eq (18) does not cover all of the small components. However I don't understand why the background scatter reflection is being singled out. It is true there is a differential scatter between when the VIIRS system views OBC BB, space view, and scene. However, the OBC BB view provides the largest non-common scattering component and its radiometric magnitude is in the range of 0.03 %. Thus there is no need for this component to be explicitly covered in Eq. (18); see Y0012891 "Calibration and stray light TIM 7/12/02 Initial partial response to Action item #6." This spurious radiance has no analog for MODIS, since the reflection from the front-end MODIS scan mirror is the scene radiance itself, not an undesired internal background. JBY3: I disagree. There are direct analogs to this on MODIS. In fact the effect on MODIS is even greater than VIIRS. This is another advantage accrued with the VIIRS rotating telescope.

Recommend replacing Eq (18) with the following:

(18rev) $L_{BCS\_PATH} = \rho_{BCS}\, \tau_{RTA}\, \varepsilon_{BCS}\, L(T_{BCS}) + (1- \rho'_{BCS})L(T_{HAM}) + \rho'_{BCS}\, L_{BCS,BKG,HAM} + L_{AFT,BKG}$

where ρ'_{BCS} is the HAM hemispherical-to-directional reflectance in the geometry in which the BCS is being viewed, ρ_{BCS} is the HAM specular directional reflectance in the geometry in which the BCS is being viewed, and τ_{RTA} is the optical transmittance of the rotating telescope (RTA) for the band in question. $L_{BCS,BKD,HAM}$ is the equivalent background radiance seen by the HAM when the BCS is being viewed. This equivalent radiance includes self-emission from the RTA and all other structures with a line of sight to the HAM. It is calculated by integrating over a hemisphere centered on the HAM the product of the BRDF of the HAM and the actual background radiance in a given direction, and dividing by the integral of the BRDF over a hemisphere. This divisor is just the hemispherical-to-directional reflectance ρ'_{BCS} that appears as a factor multiplying $L_{BCS,BKD,HAM}$ in the equation above. $L_{AFT,BKG}$ is the equivalent at-aft-optics-aperture radiance of the thermal emission of the aft-optics and all “downstream” sources up to and including the focal plane arrays. The subscript “AFT” is added to emphasize that this term includes only a portion of the instrument internal background. The instrument internal background upstream of the HAM is included in $L_{BCS,BKD,HAM}$. JBY4: It is inappropriate to use the hemispherical reflection as described above unless it is applied to the space view and scene paths. A major portion of the HAM and for that matter RTA mirrors hemispherical scatter is common for OBC BB, space view, and scene views. As such it is located in the term L_{bkg} for each path and is subtracted. As previously indicated the non common portion is less than 0.03 %; see Y0012891 “Calibration and stray light TIM 7/12/02 Initial partial response to Action item #6.”

The notation in eq (18rev) is consistent with that used in the paper from which the ATBD borrows heavily, “Prelaunch Algorithm and Data Format for the Level 1 Calibration Products for the EOS-AM1 MODIS”, by Guenther et al, July 1998. The HAM reflectance is labeled as RVS in the ATBD and is defined as a “weighting factor”. This usage of RVS is misleading. Since “RVS_{BCS}” is subtracted from 1 to provide the HAM emittance in ATBD eq (18), it is exactly the hemispherical-to-directional reflectance of the HAM, and should be clearly identified as such and conventionally labeled. This is the analog of the term $\rho^{sm}{}_{BCS}$ that appears in eq (1) of the Guenther et al. paper. JBY5: It is true that the $\rho^{sm}{}_{BCS}$ was used in the IEEE paper. It is to be noted that in latter presentation MCST started to use RVS. Furthermore, I believe RVS is more appropriate since this is a parameter that is characterized at the sensor level when the “response versus scan” is being characterized. In this paper the Greek letter ρ is used to denote a reflectance, and I recommend following this convention in the VIIRS ATBD. RVS stands for “response versus scan angle” and includes <u>as a factor</u> the specular reflectance from the HAM, not the hemispherical-to-directional reflectance. For MODIS this distinction need not be made since the scan mirror is at the front end and sees the BCS as an extended source. For VIIRS the HAM is downstream of the RTA and views the BCS through the narrow FOV of the RTA. The BCS does not fill up a hemisphere surrounding the HAM as the BCS fills ups a hemisphere surrounding the MODIS scan mirror. Therefore, I believe the distinction between these two different HAM reflectances must be made for VIIRS. Whether this distinction is quantitatively important remains to be seen. JBY6: As indicated above the distinction is quantitatively not important and thus is not explicitly stated.

Note that the transfer function from radiance at the VIIRS RTA aperture to radiance at the aft optics aperture is the product of the HAM specular reflectance and the RTA transmission. In the earth view geometry this product is: $\rho_{EV}\,\tau_{RTA}$. In eq. (38) in which the “at aperture” earth view radiance is addressed, the divisor on the RHS must be $1/(\rho_{EV}\,\tau_{RTA})$, rather than $1/RVS_{EV}$.

The at-aperture radiance for the BCS path, which is not addressed in the ATBD, would be obtained from eq (18rev) by dividing through by the transfer function $\rho_{BCS}\ \tau_{RTA}$:

$L_{BCS\_PATH} = \varepsilon_{BCS}\, L(T_{BCS}) + (1- \rho'_{BCS})L(T_{HAM})/(\rho_{BCS}\ \tau_{RTA})$
$\quad + \rho'_{BCS}\, L_{BCS,BKG,HAM}/(\rho_{BCS}\ \tau_{RTA}) + L_{AFT,BKG}/(\rho_{BCS}\ \tau_{RTA})$

(2) Recommend replacing eq (19) by the following:

(19rev) $L_{SVS\_PATH} = \rho_{SVS}\ \tau_{RTA}\ \varepsilon_{SVS}\ L(T_{SVS}) + (1- \rho'_{SVS})L(T_{HAM})$
$\quad + \rho'_{SVS}\, L_{SVS,BKG,HAM} + L_{AFT,BKG}$

$= (1- \rho'_{SVS})L(T_{HAM}) + \rho'_{SVS}\, L_{SVS,BKG,HAM} + L_{AFT,BKG}$

where $L_{SVS,BKD,HAM}$ is the equivalent background radiance seen by the HAM when the SVS is being viewed.

(3) Recommend replacing eq (20) by the following:

(20rev) $\Delta L_{BCS} = L_{BCS\_PATH} - L_{SVS\_PATH} = \rho_{BCS}\ \tau_{RTA}\ \varepsilon_{BCS}\ L(T_{BCS}) +$
$(\rho'_{SVS} - \rho'_{BCS})L(T_{HAM}) + (\rho'_{BCS}\, L_{BCS,BKG,HAM} - \rho'_{SVS}\, L_{SVS,BKG,HAM})$

JBY7: These equations will be reviewed and replaced.

(4) Recommend making eq (21) consistent with eq (20rev) above. Recommend using overbars instead of arrows over band-averaged quantities. Arrows suggest vectors.

JBY8: I agree with the comment concerning overbars rather than arrows. Mathcad was used to generate some of the equations and overbars were not available.
(5) The following statement on p. 30 not true because radiance is not a strictly linear function of digital number:

"The band-integrated radiance difference $\Delta L_{BCS}(B)$ is a function of $DN_{BCS} - DN_{SVS}$."

Recommend replacing this statement by the following:

"Since radiance is an approximately linear function of digital number, the band-integrated radiance difference $\Delta L_{BCS}(B)$ can be approximated by a function of $DN_{BCS} - DN_{SVS}$."
JBY9: I don't understand this objection. The function "$DN_{BCS} - DN_{SVS}$ "is measured data and thus is dependent upon the instrument response function which may be linear or otherwise.

(6) In equation (23) M_{BCS} is the "number of BCS frames". It is not clear what "frame" means in this context. For VIIRS there will be a number of calibration samples acquired each scan, e.g., 48 samples per scan. Recommend defining M_{BCS} as the "number of BCS samples acquired per scan", assuming this is the correct interpretation.
JBY10: This was the intent and I have no objection unless we start using "frame" as was done on MODIS. Frame and sample were equivalent in this context.

(7) In equation (23) recommend replacing the average of the calibration samples acquired in a given scan with the median. The median of 48 samples will have noise almost as low as the average, but will be robust with respect to samples contaminated by radiation (radiation "spikes") or samples that are outliers for any other reason. By "robust" I mean insensitive to outliers.
JBY11: This may be a valid point. It would be interesting to review MODIS data in this context.

(8) In Sec. 3.3.2.2 make corrections analogous to those described above for Sec. 3.3.2.1. For example, eq (26) should be replaced by:

(26rev) $L_{OBC\_PATH} = \rho_{OBC}\ \tau_{RTA}\ \varepsilon_{OBC}\ L(T_{OBC}) + (1- \rho'_{OBC})L(T_{HAM}) + \rho'_{OBC}\ L_{OBC,BKG,HAM} + (l - \varepsilon_{OBC})\ \rho_{OBC}\ \tau_{RTA}\ [F_{sh}\ L(T_{sh},\lambda_B)+$
$F_{cav}\ L(T_{cav}, \lambda_B) + F_{tele}\ L(T_{tele}, \lambda_B)] + L_{AFT,BKG}$

JBY12: Equation (26) will be modified.

Eq (27) should be replaced by:

(27rev) $\Delta L_{OBC\_PATH} = L_{OBC\_PATH} - L_{SV\_PATH}$
$= \rho_{OBC}\ \tau_{RTA}\ \varepsilon_{OBC}\ L(T_{OBC}) + (\rho'_{SV} - \rho'_{OBC})L(T_{HAM})$
$+ (\rho'_{OBC}\ L_{OBC,BKG,HAM} - \rho'_{SV}\ L_{SV,BKG,HAM})$
$+ (l - \varepsilon_{OBC})\ \rho_{OBC}\ \tau_{RTA}\ [F_{sh}\ L(T_{sh},\lambda_B) + F_{cav}\ L(T_{cav}, \lambda_B) + F_{tele}\ L(T_{tele}, \lambda_B)]$

JBY13: Equation will be modified
It is not clear why the wavelength dependence is explicit in these and other equations in Sec. 3.3.2.2 but is suppressed in the equations in Sec. 3.3.2.1. Recommend suppressing wavelength dependence in all equations for consistency.
JBY14: I agree with suppressing wavelength dependence for consistency.

(9) The second paragraph on p. 31 reads:

"T_{sh} and T_{cav} are obtained from thermistor data using fifth order polynomials that may be implemented as lookup tables. T_{HAM} and T_{tele} are from thermistors that may not be mounted on the rotating parts."

Not clear why all model temperatures, not just T_{sh} and T_{cav}, would not be obtained from thermistor data using fifth order polynomials that may be implemented as lookup tables. However, on the same page there is the following text:
JBY15: All thermistors other than those monitoring OBC BB will use fifth order polynomial.

"T_{OBC} data comes from thermistor temperature sensors. In order to obtain very low uncertainty a three component natural log equation is used."

It is not clear what this "three component natural log equation" is, or why it might be better than the fifth order polynomials used for other temperatures.

Clarify why different functions of thermistor readings will be used for different model temperatures, and provide the "natural log equation" referred to above.
JBY16: The three component log expression is –

$$T(R) = \frac{1}{a_1 + a_2 \cdot \ln(R) + a_3 \cdot \ln(R)^2 + a_4 \cdot \ln(R)^3}$$

Where

- R – thermistor resistance
- T – thermistors temperature
- A – coefficients are fitted to calibration data, T, R

This expression has been shown to fit thermistors function with an uncertainty of ˜ < 0.002 K. The fifth order polynomial fit has significantly greater uncertainty.

Regarding the statement:

"T_{HAM} and T_{tele} are from thermistors that may not be mounted on the rotating parts."

there should be some statement about where these temperatures are measured if they are not on the rotating parts themselves, and a justification for why it is believed that the thermistors used will track the rotating object temperatures, such as the HAM surface and telescope baffle, with sufficient accuracy. The text should address the fact that the telescope baffle may be directly illuminated by the sun, while the thermistor(s) used for this temperature may not be illuminated. Similarly, the HAM thermistor may not be in thermal equilibrium with the HAM surface, as Neal Baker has pointed out, and therefore may not provide the needed 1 K accuracy.
JBY17: It appears to me that this kind of detail is questionable in the ATBD. If there are questions they should be treated at the sensor level. The required temperature parameters need to be passed such that they available for the ATBD. Justification is done at the sensor level.
There should also be some statement clarifying the location of the thermistors that will be used to calculate the instrument temperature T_{inst}.

JBY18: I expect this will be done; however, it is likely to be associated with EDU thermal vacuum testing. Current assessment is documented in Y0012853 entitled “Calibration and stray light TIM 7/12/02 Response to Action items 3 & 9”

(10) The averaging over previous scans prescribed by eq. (32) may defeat the purpose of thermistors that are strategically placed to monitor solar impingement. Unlike MODIS, solar illumination within the VIIRS cavity can change abruptly. The temporal smoothing of the linear response term might worsen rather than improve VIIRS emissive band calibration.
JBY19: To date there are no indications from the VIIRS thermal model that there are abrupt changes any place within the cavity other than those associated with the solar diffuser screen. These significant changes are associated with the thin screen structures that have small heat capacity. I know of no other comparable structures. Supporting analysis is documented in Y0012853 entitled “Calibration and stray light TIM 7/12/02 Response to Action items 3 & 9”.

(11) In the last full paragraph on p. 32 the elevation of the OBC to 315 K is described. The data from this operation are said to be used to verify the stability of the 0’th and 2nd order coefficients determined pre-launch. Suppose the measurements indicate that the pre-launch coefficients have not been stable and new values are required. What is the algorithm for updating these coefficients? This algorithm should be described in the ATBD.
JBY20: I will plan on providing this.

(12) The rationale for the correction of dn_{EV} by temporal interpolation of calibration data described on pp. 32-33 is compensation for 1/f noise drift in the instrument internal background, according to the Guenther et al. paper. This rationale is not provided in the ATBD. Recommend including this rationale in the ATBD to make the ATBD self-contained.
JBY21: There will be no algorithm for 1/f drift for VIIRS.

(13) Since the reference point for radiance is the entrance aperture of the aft-optics, the reciprocal of the transmission of the RTA is needed as a multiplier in Eq. (38).
JBY22: Calibration and scene retrieval methodology to handle this situation needs to be developed. The method must provide means for on orbit update since RTA transmission (reflection) could change. This will be included in the review / perturbation analysis associated with algorithm modification.

(14) According to the ATBD the pre-launch characterization using the BCS is used to generate the small 0’th and 2nd order coefficients a_{0_BCS} and a_{2_BCS}. This by itself is a very modest “calibration transfer”. The Guenther paper refers to a potentially important correction to the measured OBC temperature ΔT_{OBC} based on prelaunch measurements using the BCS. Jim Young stated in the delta-CDR that this temperature correction may also be needed for VIIRS. In fact, if it is needed for MODIS one would expect that it is also needed for VIIRS. Therefore, recommend describing this correction and the method by which it is obtained in the ATBD. This correction is mentioned at the end of section B on p. 1147 of the Guenther et al. paper.

JBY23: During early phases of MODIS we anticipated that some OBC BB temperature delta might be required when data acquired in thermal vacuum from BCS and OBC BB required reconciliation. No such effect was observed.

Comments on VIIRS Radiometric Calibration ATBD, Version 5, Revision 1, May 2002
F. De Luccia
29 July 02

Part 2 (?): Comments on Reflective Band Calibration (Sec. 3.3.1 Reflective Bands)

(1) Eq (1) expresses a radiance “LL” in terms of dn, the signal difference between the SIS and SVS. Both “LL” and “dn” need to be better defined in the ATBD. “dn” should presumably be defined as an average over a number of samples, so that noise does not affect the derivation of the polynomial coefficients. The reference Y5235 does not address this averaging. Sec. 3.3.2.1 addresses this averaging in detail, in terms of samples per scan and multiple scans, for the emissive band calibration. For clarity and consistency, recommend explicitly defining the averaging to be performed to generate “dn”. Also, based on Y5235 LL is a radiance level within the dynamic range of the sensor, the absolute value of which need not be known. LL is varied within the dynamic range of the sensor, by changing the SIS lamp current, with and without an attenuator in the optical path. The derivation of the polynomial coefficients as described in Y5235 is much more complex than ATBD eq (1) would suggest, and is apparently designed to eliminate the need for knowledge of the absolute radiance values. Recommend adding explanatory text in the ATBD stating that the polynomial coefficients are determined by a methodology that eliminates the need for knowledge of the absolute radiance as the radiance is varied across the sensor dynamic range. Recommend defining LL explicitly, e.g., as a relative radiance or the calibrated radiance up to a scale factor.
JBY1: Equations (1) through (4) relate to data acquired during prelaunch thermal vacuum. As such they were included as background information. If their inclusion is detrimental to understanding the ATBD perhaps they should be deleted. The coefficients given in equation (4) are the only elements used in the initial post launch on orbit calibration.
JBY2: The parameter, LL, is a relative radiance function

(2) Eq.(2) provides a re-scaling coefficient based on a single calibrated radiance level of the SIS. One can only infer that the absolute radiance from the SIS is known for (at least) one lamp current value, but not for the range of lamp current values needed to determine the sensor response over the dynamic range. Otherwise, LL in eq (1) would be a calibrated radiance and no re-scaling would be necessary. To improve clarity, recommend explaining why the absolute SIS radiance is not known at the multiple lamp current levels used to determine the sensor response.
JBY3: It appears one source of confusion is that two different SIS is being considered. The SIS used for relative response measurement, per Y5235, does not have an absolute radiometric calibration. The lamp current in this small SIS is varied such that the VIIRS band dynamic range can be covered. The lamp currents used for the SIS(100) are never varied. The approach described in Y5235 enables a more accurate characterization of VIIRS relative response function than is possible with the SIS(100).

(3) The text of point (1) on p. 22 reads:

"1. Solar diffuser Bi-directional Reflectance Distribution Function (BRDF) over the total useful angular and wavelength domain for reflective region, BRDF(φ_h , φ_v , λ). (Note: angles φ_h and φ_v are used in the calculation of the solar illumination angle of incidence on the solar diffuser)"

The angles φ_h and φ_v need to be explicitly defined. It is stated that these parameters are used to determine the solar illumination angle of incidence on the solar diffuser (SD), but the parameters themselves are not explicitly defined. The subscripts "h" and "v" suggest "horizontal" and "vertical", but the reader cannot infer a definition from the text.
JBY4: Subscripts h and v do correspond to horizontal and vertical. Horizontal relate to sensor XY plane and vertical is perpendicular to XY plane

Also, the BRDF of the SD would need to be characterized for at least two different look angles, that of the telescope during the SD calibration look and that of the SDSM. These angles should be included as arguments of the BRDF, which is in general a function of four distinct angles, not two.
JBY5: There should be an associated view direction BRDF(ϕ_h, ϕ_v, ϕ_{view}). This view direction is only associated with VIIRS sensor. The SDSM is a ratioing radiometer and does not require this data.

(4) The text of point (4) on p. 22 reads:

"4. Response versus scan angle, RVS(B, λ)"

RVS(B, λ) needs to be defined. In the section on emissive calibration this parameter is identified with one factor in the overall sensor response, the reflectance from the HAM. If only the reflectance of the HAM is meant, recommend using conventional terminology and symbol ("specular reflectance of HAM" and "ρ" as the symbol for reflectance).
JBY6: This parameter is characterized with a system level test entitled "response vs scan". As indicated in the emissive comments I believe that RVS is an appropriate term.

(5) The text of point (5) on p. 22 reads:

"5. However, the SDSM tracks solar diffuser BRDF changes for the VIS and NIR regions. The SDSM does not have bands in the SWIR region. An assumption is made (as was done in the MODIS system) that there is no degradation of solar diffuser BRDF in SWIR bands (i.e. M8, M9, M10, M11, and I3)."

Since the VIIRS SD receives much more solar exposure than the MODIS SD, will the assumption that the SWIR BRDF is constant be valid for VIIRS? Recommend adding a statement justifying the validity of this assumption for VIIRS.
JBY7: ??

(6) Based on Eq. (5) RVS(θ_{SD}) is evidently the specular reflectance of the HAM in the geometry in which the SD is viewed. In any case, as part of the response function of VIIRS, it does not belong in an expression for the at-aperture radiance. Eq. (5) describes a correction to the pre-launch calibration coefficients given in Eq. (4). The radiance on the LHS of Eq. (4) is presumably the at-aperture calibrated radiance from the SIS. The at-aperture radiance when viewing the SD is correctly given by the numerator of the RHS of Eq. (5), if RVS(θ_{SD}) is deleted. To maintain consistency with Eq. (4), recommend deleting RVS(θ_{SD}) from Eq. (5), and including this factor of RVS(θ_{SD}) on the RHS of Eq. (7). The pre-factor multiplying the expression in braces in Eq. (7) would then be (RVS(θ_{SD})/RVS(θ_{EV})) rather than (1/RVS(θ_{EV})). Although this change makes no difference in the end result for the at-aperture radiance, it is advisable for clarity and consistency.

JBY8: It is recommended that the equations remain as given in ATBD.

(I am assuming that that RVS has no significant wavelength dependence within a band, so that it is a factor of the integral over wavelength, not an essential part of the integrand. I am also assuming that Raytheon does not intend the reference point for radiance to be at the entrance to the aft-optics for the intermediate calibration equations. If this were the case, then the RTA transmission would appear, although it would cancel out in the expression for the at-aperture earth view radiance.)

(7) Delete RVS(θ_{SD}) from the RHS of Eq. (8), and include it as a factor on the RHS of Eq. (9). Make analogous changes in Eqs (12), (14), (15) and (17).

JBY9: It is recommended that the equations remain as given in ATBD.

Comments on VIIRS Radiometric Calibration ATBD, Version 5, Revision 1, May 2002
F. De Luccia
29 July 02
Part 3 (?)
(1) Sec. 2.2.5, p. 14
The following statement appears in the paragraph at the bottom of the page:

"Though the signals from these objects are mainly of concern to reflective band DC restoration, the architecture of the Sensor requires all bands to be DC restored at the same time."

It is not obvious why the space view could not be used for DC restore of the emissive bands. How does the "architecture of the Sensor" preclude this possibility?
JBY1: Space view could be used for DC restoration. However, if it were then a method would be needed to handle cases where the moon was in the space view. Thus it was decided that the sensor could be made simpler by DC restoring on the OBC BB. This approach was also used on MODIS.

(2) Sec. 2.2.5, pp. 14-15

The following statements appear in the paragraph beginning at the bottom of page 14:

"Therefore, the actual offset employed for emissive band DC restoration must be calculated based on the temperature of the blackbody and the signal that should result from viewing it. This is done using an on-board look-up table that indicates the expected band output as a function of blackbody temperature, and by having the flight software adjust the offset level based on the difference between the actual and expected outputs."

In order to determine the appropriate offset for emissive bands, the digital number during the space view must be calculated from the digital number (suitably averaged) during the blackbody look. This must involve multiplying the blackbody radiance by the sensor responsivity (dn/dL) to determine the portion of the average digital number from the blackbody look that can be attributed to the blackbody. The remainder can be attributed to the pedestal and would determine the offset. The sensor responsivity changes on orbit and is measured and updated by the on-board calibration process. Therefore, it would seem that the look-up tables used to determine the offset must be updated on orbit to compensate for changes in sensor responsivity. The updating of the look-up table is non-trivial and the algorithm for this update should be described in the ATBD. If no updates are envisioned, an explanation is needed for how a static look-up table can accomplish the objectives of DC restore given that sensor response will change on orbit.

Ed Clement: Since modifications to the data resulting from DC restoration are removed as part of the calibration process, the requirement to maintain the band output near 200 counts is not very tight. Small variations in responsivity can be ignored as long as the same DC offset is present during Earth and Space view data collections, and as long as there is sufficient dynamic range headroom. As previously described, the VIIRS DC restoration algorithm will be table based, as it currently is on MODIS. This pre-computed table provides an ideal output level for each band based on blackbody temperature. The on-board algorithm simply determines the difference between the actual and ideal band output and then programs an offset corresponding to this difference into the band. The 'meat' of the algorithm is in the table. I note that no changes have been required for either MODIS instrument since launch.

Raytheon is not opposed to providing additional details on the DC restoration process, however, this might better be documented in the flight software description than the calibration ATBD.

(3) Sec. 3.1.2, p. 19

The third bullet in the listing of offline processing studies is:

"TEB Response Versus Scan (RVS) study with nadir door scanning"

Does Raytheon envision taking emissive band data with the nadir doors closed prior to outgassing? Further explanation of this bullet is needed.
Ed Clement: I believe this was quite useful on MODIS and thus would expect to do it on VIIRS. We believe that useful information is available from comparing data collected from the inside of the door during ground and initial on-orbit measurements. For example, door data from the same scan angle, but from different sides of the HAM could be used to determine if a change occurs during launch. Though this data would probably not be directly used for calibration purposes, it could prove useful when investigating some other concern with instrument data. Note that data was not collect from MODIS on-orbit prior to on-orbit outgassing, and would not be for VIIRS, either.

(4) Table 3, p. 35

Recommend inserting "(1/2 Max Radiance)" after "Mid-range radiance" for greater specificity and consistency with the Sensor Spec. Recommend a footnote explaining that there is no uncertainty requirement where values are not provided in the table, i.e., for Stages 1A, 1B, and 2 for mid-range radiance, and for Stage 3 for minimum radiance.
Dick Julian: Thank you for these suggested changes, which clarify Raytheon's intended meaning. They should be incorporated with the next revision of the ATBD.

(5) Secs. 3.4 and 4.2

Recommend including more detail on the look-up tables. The tables and their dimensionalities should be identified. Tables that are static should be distinguished from those that are updated post-launch. Tables that are used to provide inputs to interpolation routines should be distinguished from those that are used directly. Future revisions of the ATBD should include even more detail, particularly after EDU testing reveals the full set of corrections and adjustments that may be needed.

Ed Clement: Actually three categories should be considered for tables: Fixed (never updated), Frequently Updated, Update As Required (implying infrequent updates).

(6) Eq 10, p. 24, Eq. 17, p. 26, and Eq. 38, p. 34

Recommend including a table of parameters for each equation expressing the final earth view product (radiance or reflectance) similar to Table 3.2.1 in the MODIS Level 1B ATBD (ATBD-01,Ver 2.0) that includes the parameter description, type, and index for all parameters used in the equation. Parameter types would include “pre-launch measured or model-estimated variables, represented as LUTs”, “pre-launch measured and post-launch interpolated (or extrapolated) variables”, “on-line scan-by-scan measured variables”, and “off-line measured variables”, as applicable. The index would specify a symbol for each dimension of the parameter, e.g., detector, band, mirror side, gain state, etc.

The MODIS Level 1B ATBD also includes flowcharts illustrating the calibration processing flow. (See, for example, Sec. 3.2.4.) It would be beneficial to incorporate similar flowcharts in future revisions of the VIIRS Radiometric Calibration ATBD.
Ed Clement: Good suggestions that will be considered for the next revision of the ATBD.